

Allochthonous blue spruce in Central Europe serves as a host for many native species of sawflies (Hymenoptera, Symphyta)

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Abstract

In air-polluted mountain areas of the Czech Republic, including the Ore Mountains, pure forest stands of introduced blue spruce (*Picea pungens*) were established in the 1980's. We studied the Symphyta (Hymenoptera) fauna in the canopies of these trees at four sites and in the canopies of adjacent *Picea abies* trees at one of these sites by beating tree branches. For the first time, Nearctic blue spruce is reported as a host for 17 European species of Symphyta (sawflies). Diprionids in the genus *Gilpinia* were the most abundant sawflies on *P. pungens* and were more abundant on *P. pungens* than on the native *Picea abies*. Spruce pamphiliids in the genus *Cephalcia* were also more abundant on *P. pungens* than on *P. abies*, while the abundances of representatives of the tenthredinid genera *Pikonema*, *Pachynematus*, and *Pristiphora* were similar on *P. pungens* and *P. abies*. Our results indicate that many species of European spruce Symphyta are able to use the allochthonous species *P. pungens* as a host.

Keywords

Picea pungens, *Picea abies*, Symphyta, Diprionidae, Tenthredinidae, Pamphiliidae, larvae

Introduction

In Central Europe, *P. abies* (L.) Karst is the only native species of spruce (Schwenke 1978). Many introduced spruce species including of the blue spruce, *Picea pungens* Engelm, are occasionally cultivated in urban areas. Beginning in the 1980s, pure stands of *P. pungens* have been planted in an area of about 100 km² in the air-polluted mountain regions of the Czech Republic. *P. pungens* was thought to require only modest soil resources, to have a high tolerance to sulfur oxide air pollution, and to have the ability to resist or avoid ungulate herbivores (Šika 1976, Tesař 1981, Balcar 1986, Jirgle et al. 1983, Kubelka et al. 1992). The assumption about high resistance to air pollution was found to be incorrect, however, because the needles of young *P. pungens* and *P. abies* exhibit the same degree of damage in response to air pollutants (Soukupová et al. 2001).

Many forest pests including many defoliators feed on spruce (Pschorn-Walcher 1982).

At least 34 species belonging to three families of Symphyta (32 species in Central Europe) feed on needles of native spruce in Europe. These feeders include Pamphiliidae with at least nine species of *Cephalcia* (Viitasaari 2002), Diprionidae with four *Gilpinia* species and *Microdiprion fuscipennis* (Forsius, 1911) (Kontuniemi 1960, Viitasaari and Varama 1987), and Tenthredinidae with 15 *Pristiphora* s.l. (Beneš and Křístek 1979, Kajmuk 1988), two *Pikonema* and three *Pachynematus* s.l. (Taeger et al. 1998). *Pristiphora tenuiserra* (Lindqvist, 1959), for which the host plant is unknown, may also be a spruce feeder (Holuša and Roller 2000). New generic nomenclature of Nematinae (Prous et al. 2014) has been omitted (*Pikonema* and *Pachynematus* are currently treated as members of a vast genus *Euura*) with respect to applied entomology.

Although the blue spruce *P. pungens* is planted in the extensive, air-polluted areas of the Czech Republic, the Symphyta fauna developing on this allochthonous plant have not been thoroughly studied. One reason is that serious outbreaks of pests have not occurred during the 25- to 30-year period following the establishment of pure stands of *P. pungens* in the Ore Mountains (Holuša and Holuša 2003).

The host status of *P. pungens* for European native Symphyta is unknown. The goals of this study were (i) to identify the sawflies that feed on *P. pungens* in the Czech Republic and (ii) to compare the abundances of these sawflies on the native *P. abies* and on the introduced *P. pungens*.

Methods

Sawflies were studied in three localities in the Ore Mountains (NW Czech Republic) (Table 1). Two localities (Jirkov, Dlouhá louka) had pure stands of *P. pungens*, and one locality (Sněžník) had a pure stand of *P. pungens* and a pure stand of *P. abies* that were 100 m apart.

Sawfly larvae and adults were sampled by beating tree branches and collecting the falling insects on a sheet stretched on a 0.5 × 1 m metal frame. On each sampling date, 10 samples were collected at each of the four stands. For each sample, two branches

Table 1. Characteristics of studied stands.

Locality	Tree species	Geographic characteristics	Altitude (m asl)	Stand density	Age of stand [years]	Area/percentage of spruce forest in district	Native forest type	Annual mean temperature and total precipitation
				[%]				
Jirkov	<i>P. pungens</i>	50°33'11"N, 13°22'59"E	875	90	25–36	14.43 km ² /	<i>Fageto - Piceetum acidophilum</i>	4–4.5 °C
						15.4%		1050–1200 mm
Dlouhá louka	<i>P. pungens</i>	50°39'00"N, 13°38'04"E	865	70	34	29.37 km ² /	<i>Fageto - Piceetum acidophilum</i>	4–4.5 °C
						22%		1050–1200 mm
Sněžník	<i>P. pungens</i>	50°47'28"N, 14°04'33"E	576	70	27–31	4.87 km ² /	<i>Piceeto - Fagetum acidophilum</i>	4.5–5.5 °C
						4.5%		900–1050 mm
Sněžník	<i>P. abies</i>	50°47'30"N, 14°04'15"E	576	70	19	28.76 km ² /	<i>Piceeto - Fagetum acidophilum</i>	4.5–5.5 °C
						26.6%		900–1050 mm

were selected at random in the crowns of 10 trees, the branches were located from 0.7 to 2.5 m above the ground, and the sampled trees were in a line with 10 m between adjacent trees. Trees were sampled on 17 May, 15 June, 14 July, 15 August, 15 September, and 15 October 2007. Thus, one sample consisted of insects collected from one stand (a total of 20 branches on 10 trees) across all six sampling dates.

The collected insects were stored in 75% ethanol. Larvae were identified using the keys of Beneš and Křístek (1979), Battisti and Jiang-hua Sun (1996), Battisti and Zanocco (1994), Martinek (1988), and Zanocco and Battisti (1995). Very young larvae (first and second instars) were identified only to genus (*Cephalcia*, *Gilpinia*, and *Pristiphora*). The current knowledge of larvae allows the identification of some *Pachynematus* s.l. and *Pristiphora* s.l. only to the subgeneric level and are here referred to as the *Epicenematus* and *Sharliphora* species groups, respectively. Adult sawflies were identified using the keys of Beneš and Křístek (1979), Viitasaari (2002), and Zhelokhovtsev (1988). The nomenclature follows Taeger and Blank (2011), and host plants are given according to Taeger et al. (1998) unless stated otherwise.

The data of larvae per locality were not normally distributed. When the abundance of a sawfly species was > 10 on both *P. abies* and *P. pungens* at Sněžník, the values were compared with a Wilcoxon pair test in Statistica 12.0.

Results

In total, 748 larvae and 79 adults of 36 species of sawflies were collected (Table 2). Among the 36 species, 23 have been previously associated with spruce, and the 13 have been previously associated with other plant species (Table 2). Larvae obtained from the branches of *P. abies* (N=127) and *P. pungens* (N=621) belonged to 12 and 18 species of Symphyta, respectively.

Table 2. Total numbers of sawflies (Hymenoptera: Symphyta) collected on *P. abies* and *P. pungens* in the Czech Republic (plus information on known host plants for each species of sawfly). The sawflies were collected from 20 branches per stand (two branches on each of 10 trees) in three *P. pungens* stands (at Jirkov, Dlouhá louka, and Sněžník) and in one *P. abies* stand (at Sněžník) on six sampling dates from spring to fall in of 2007. Sawfly species feeding on spruce are in bold. When the abundance of a sawfly species (larvae + adults) was > 10 on both *P. abies* and *P. pungens* at Sněžník, the values were compared with a Wilcoxon pair test (an asterisk indicates a significant difference, and n.s. indicates a non-significant difference). The information on known host plants is from Taeger et al. (1998) unless indicated otherwise.

Sawfly species	Number of larvae		Wilcoxon pair test	Number of adults		Known hosts
	On <i>P. abies</i> at Sněžník	On <i>P. pungens</i> at all three stands (and at Sněžník in brackets)		On <i>P. abies</i> at Sněžník	On <i>P. pungens</i> at all three stands	
<i>Arge fuscipes</i> (Fallén, 1808)				1	1	<i>Salix</i> , <i>Betula</i>
<i>Cephalcia</i> sp.	5	17(4)				
<i>Cephalcia abietis</i> (Linné, 1758)		11(1)			6	<i>P. abies</i> , <i>P. obovata</i> , <i>P. koraiensis</i>
<i>Cephalcia alpina</i> (Klug, 1808)	2	16(2)				<i>P. abies</i> , <i>P. obovata</i> , <i>P. koraiensis</i> , <i>P. jezoensis</i>
<i>Cephalcia arvensis</i> Panzer, 1805		16(7)		4	11	<i>P. abies</i> , <i>P. obovata</i> , <i>P. koraiensis</i> , <i>P. jezoensis</i>
<i>Cephalcia erythrogaster</i> (Hartig, 1837)		1(0)		1		<i>P. abies</i> , <i>P. koraiensis</i>
<i>Cephalcia fulva</i> Battisti & Zanolco, 1994	1	6(2)				<i>P. abies</i> , <i>P. koraiensis</i>
<i>Dineura virididorsata</i> (Retzius, 1783)					1	<i>Betula</i>
<i>Dolerus gonager</i> (Fabricius, 1781)					1	Poaceae
<i>Dolerus nigratus</i> (O.F.Müller, 1776)					2	Poaceae
<i>Gilpinia</i> sp.	17	84 (42)	2.36*			
<i>Gilpinia abieticola</i> (Dalla Torre, 1894)	19	98 (19)	0.00 n.s.		2	<i>P. abies</i> , <i>P. obovata</i> , <i>Pinus pumila</i> (probably missidentification, Karel Beněš pers. comm.)
<i>Gilpinia bercyniae</i> (Hartig, 1837)	2	134 (4)	0.80 n.s.			<i>P. abies</i> , <i>P. obovata</i> (In N. America <i>P. glauca</i> , <i>P. sitchensis</i> , <i>P. pungens</i> , <i>P. mariana</i> , <i>P. rubens</i> , <i>P. pungens</i> (Quarantine PEST data Sheet))
<i>Gilpinia polytoma</i> (Hartig, 1834)	7	19 (19)	1.85 n.s.			<i>P. abies</i> , <i>P. obovata</i> , and <i>P. smithiana</i> (Viitasaari (1987)
<i>Macrophya sanguinoleta</i> (Gmelin, 1790)					1	<i>Veronica</i> , <i>Galeopsis</i> , <i>Senecio</i>
<i>Pachynematus lichtwardti</i> Konow, 1903					2	unknown
<i>Pachynematus (Epicenematus)</i> sp.	21	95(17)	0.65 n.s.			

Sawfly species	Number of larvae		Wilcoxon pair test	Number of adults		Known hosts
	On <i>P. abies</i> at Sněžník	On <i>P. pungens</i> at all three stands (and at Sněžník in brackets)		On <i>P. abies</i> at Sněžník	On <i>P. pungens</i> at all three stands	
<i>Pachynematus montanus</i> (Zaddach, 1883)					1	<i>P. abies</i> , and <i>P. obovata</i> (Popov & Kajmuk 2010)
<i>Pachynematus styx</i> (Benson, 1958)					1	<i>P. abies</i>
<i>Pachyprotasis rapae</i> (Linné, 1767)					7	oligophagous
<i>Pamphilus hortorum</i> (Klug, 1808)					1	<i>Rubus</i>
<i>Pikonema insigne</i> (Hartig, 1840)						<i>P. abies</i> , and <i>P. obovata</i> (Popov & Kajmuk 2010)
<i>Pikonema scutellatum</i> (Hartig, 1840)	11	11(1)	1.94 n.s.	1	1	<i>P. abies</i> , <i>P. obovata</i>
<i>Pristiphora</i> sp.	17	39(12)	1.40 n.s.			
<i>Pristiphora abietina</i> (Christ, 1791)	2	6(4)				<i>P. abies</i> , <i>P. obovata</i> (Popov & Kajmuk 2010), <i>P. obovata</i> and <i>P. sitchensis</i> (Kollar 2007, Austara et al 1984)
<i>Pristiphora compressa</i> (Hartig, 1837)	8	41 (12)	0.92 n.s.		2	<i>P. abies</i> , and <i>P. obovata</i> (Popov & Kajmuk 2010)
<i>Pristiphora decipiens</i> (Enslin, 1916)	4	15(6)			1	<i>P. abies</i>
<i>Pristiphora gerula</i> (Konow, 1904)	1	2(0)				<i>P. abies</i>
<i>Pristiphora leucopodia</i> (Hartig, 1837)	2	2(0)				<i>P. abies</i>
<i>Pristiphora pallida</i> (Konow, 1904)					1	<i>P. abies</i>
<i>Pristiphora pseudodecipiens</i> Beneš & Krístek, 1976	6	6(0)		1	1	<i>P. abies</i>
<i>Pristiphora robusta</i> (Konow, 1895)		1(0)				<i>P. abies</i> , and <i>P. obovata</i> (Popov & Kajmuk 2010)
<i>Pristiphora saxsenii</i> (Hartig, 1837)		7(0)				<i>P. abies</i>
<i>Pristiphora</i> (<i>Sharliphora</i>) sp.	2	9(2)				
<i>Pristiphora nigella</i> (Förster, 1854)					2	<i>P. abies</i>
<i>Pristiphora parva</i> (Hartig, 1837)				1		<i>P. abies</i>
<i>Tenthredo atra</i> Linné, 1758					1	oligophagous
<i>Tenthredo mesomela</i> Linné, 1758					3	oligophagous
<i>Tenthredo olivacea</i> Klug, 1817					2	oligophagous
<i>Tenthredopsis ornata</i> (Serville, 1823)					3	<i>Brachypodium</i>
<i>Tenthredopsis scutellaris</i> (Fabricius, 1804)				1	15	<i>Festuca</i> , <i>Poa</i> , <i>Dactylis</i> , <i>Elytrigia</i>
Total	127	621		10	69	

Five species in the genus *Cephalcia* were only found in small numbers and on several specimens of *P. pungens*, and two of these five species were found on *P. abies* (Table 2). The abundance of larvae belonging to *Cephalcia* species did not differ between samples from *P. abies* and *P. pungens* (Table 2).

Diprionids of the genus *Gilpinia* were the most abundant sawflies in the samples and represented 51.8% and 35.4% of the specimens collected from *P. pungens* and *P. abies*, respectively. *Gilpinia abieticola* and *G. hercyniae* were the most numerous species, while *G. polytoma* was recorded exclusively in the *P. abies* and *P. pungens* stands at Sněžník. Although the *Gilpinia* abundance did not differ between *P. abies* and *P. pungens* stands, more first and second instar larvae of *Gilpinia* were found on *P. pungens* than on *P. abies* at Sněžník (Table 2).

Almost identical species (both larvae and adults) of spruce tenthrinids (*Pristiphora*, *Pachynematus*, and *Pikonema*) were found in the *P. abies* and the *P. pungens* samples, and the abundance of larvae of each species did not differ on *P. abies* vs. *P. pungens*. Based on larvae, *Pachynematus* (*Epicenematus*) sp. followed by *Pristiphora compressa* were the most abundant species in *P. pungens* samples (Table 2).

Across all species, sawfly abundance did not statistically differ on *P. abies* vs. *P. pungens* at Sněžník ($z=0.59$, $p>0.05$).

Discussion

In the current study, a total of 18 sawfly species were collected from *P. pungens* in the Ore Mountains of the Czech Republic. This represents 56% of the species of needle-feeding spruce sawflies in Central Europe ($N=32$) (Beneš and Křístek 1979, Holuša 2005, Jachym et al. 2005). *P. pungens* was recorded as a new host for 17 of these Palearctic species. The 13 additional species have not been associated with spruce as a host, and their occurrence in the samples was accidental (Table 2).

In Central Europe, eight species of Pamphiliidae are associated with *P. abies* (Holuša et al. 2007). We confirmed that *P. pungens* is a host for *C. abietis*, *C. arvensis*, *C. alpina*, *C. fulva*, and *C. erythrogaster*. In Europe, the most abundant sawfly has been *C. abietis* followed by *C. arvensis*, and mass outbreaks of *C. abietis* (Escherich 1942, Pschorn-Walcher 1982, Kula 1987, Liška et al. 1991) and local outbreaks of *C. arvensis* and *C. alpina* have been repeatedly reported (Křístek and Švestka 1986, Martinek 1991, 1992, Liška 1999, Zanolco and Battisti 1995).

The most abundant larvae collected from *P. pungens* were species of *Gilpinia*. All three spruce diprionids (*G. abieticola*, *G. hercyniae*, and *G. polytoma*) are common in spruce stands in Central Europe (Úradník and Kulfan 2002, Holuša and Roller 2004), but the three species can differ in abundance, dominance, and frequency (Martinek 1960, Úradník and Kulfan 2002, Holuša and Roller 2004). Until this study, *G. hercyniae* has been the only European diprionid known to feed on *P. pungens* (Balch 1939).

The numbers of spruce tenthrinids in the genera *Pikonema*, *Pristiphora*, and *Pachynematus* were similar on *P. pungens* vs. *P. abies*. We suspect that the L1 and L2 lar-

vae identified as *Pachynematus* (*Epicenematus*) sp. are *P. montanus*, although *Pachynematus* (*Epicenematus*) *pallens* (Hartig, 1837) and the extremely rare *P. styx* may also be present in the studied stands. The former species has the ability to rapidly increase (Kolubajiv 1939, Martinek 1994, Reisenberger and Krehan 1993) and is widespread not only in *P. abies* stands (Holuša 2002) but also in *P. pungens* stands (this study). Another species that can rapidly increase, *Pikonema scutellatum*, was rarely collected in the study area, although it is common in Central Europe (summarised by Holuša and Lubojacký 2008). Because one adult of the very rare species *Pikonema insigne* was found in the *P. pungens* stand at Sněžník, we suspect that *P. pungens* is a host for this species.

The larvae of eight *Pristiphora* species plus adults of *P. (Sharliphora) pallida* and *P. (Sharliphora) parva* were collected on *P. pungens*, but it is very probable that larvae of *Pristiphora* (*Sharliphora*) sp. were represented mainly by the larvae of *Pristiphora nigella*. *P. abietina* is a pest of Norway spruce in Central Europe (Pschorn-Walcher 1982) and often occurs in high numbers with *Pikonema scutellatum* and *Pachynematus montanus* (Kolubajiv 1939, 1958). However, *P. abietina* prefers lower altitudes where it can rapidly increase (Martinek 1960, Holuša 2002). Thus, the low abundance of this species in the studied stands is in accordance with the aforementioned studies. *P. compressa*, the most common *Pristiphora* in *P. pungens* stands, could be even more abundant than *P. abietina* in mountain stands of *P. abies* (Úradník and Kulfan 2002). We also found *P. pallida* and *P. robusta*, that have been very seldom recorded in spruce stands (Forsius 1911, Křístek 1973).

In the investigated air-polluted areas the native *P. abies* stands are almost completely absent because this tree was not used for forest regeneration in the 1980's (Kubelka et al. 1992). Our study indicates that a range of *P. abies* defoliators use *P. pungens* as a substitute host plant. This phenomenon has also been documented for herbivorous moths. Of the 50 moth species that feed on *P. abies* in Europe, 31 have been found to develop on the needles and buds of *P. pungens* (Kulfan et al. 2010).

The spruce-feeding sawflies in Central Europe are not strictly monophagous on *P. abies*. Most of these species have been observed to feed on other Palearctic spruces like *Picea obovata* (Ledeb.), *Picea koraiensis* Nakai, and *Picea jezoensis* (Sieb. & Zucc.) (Taeger et al. 1998). Before the current study, however, Nearctic spruces had not been reported as hosts for European Symphyta other than for *G. hercyniae* (Balch 1939).

Because the abundance of sawfly larvae and adults was low in the current study (compare with Holuša 1999, Holuša and Lubojacký 2008), we did not observe substantial defoliation of trees in the *P. pungens* stands in 2007. Severe defoliation of *P. pungens* was reported in the 1970s and early 1980s even at altitudes of 900 m (Holuša and Holuša 2003). Many sawfly outbreaks occurred throughout the Czech Republic in the early 1980s. The most recent instance of severe defoliation and subsequent chemical treatment was in 1982 (Holuša and Holuša 2003). The regeneration of *P. abies* stands has recently increased in the Ore Mountains (Šrámek et al. 2008), and thus populations of sawflies living on *P. pungens* may recolonize the *P. abies* stands in the future. Although sawflies have not recently caused extensive damage to spruce in Central Europe, the spruce sawflies are in a latency period in this region (Holuša et al. in prep.), and local outbreaks have occasionally occurred (Egginger et al. 2014).

Conclusions

Our results demonstrate that European spruce sawflies are able to use the diverse allochthonous spruce species as hosts and may show stronger preferences for the new host, here especially *P. pungens*, than for the native host, *P. abies*.

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